
Metallicity and mean age across M33

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New wide-field near-infrared (NIR) imaging observations of M33 were obtained from UKIRT. These show a large population of intermediate-age stars considerably improving on previous NIR data. The spatial distribution of super giant stars, carbon-rich (C-rich or C stars) and oxygen-rich (O-rich or M stars) asymptotic giant branch (AGB) stars distinguished from the NIR colour-magnitude diagram (CMD) have been studied as well as the C/M ratio. The K_s magnitude distribution has been interpreted using theoretical models to derive the mean age and the mean metallicity across M33.

1 Introduction

M33 is the third brightest Local Group (LG) member. It is of Sc II-III type, thus intermediate between large spirals and dwarf irregular galaxies. It has a nucleus, a disk and a halo and its stellar population exhibits both a metallicity and age gradient ([1]).

NIR observations of the stellar content of M33 began with [8]. While looking for a signature of a bulge component, which was not found, they observed

numerous intermediate-age stars in the central $7.6'$ of the galaxy down to $K \sim 17 - 18$. Several years later ([10]) reaching $K \sim 22$ detected young, intermediate-age and old stars in the central $22''$. Wide-field relatively shallow observations ($K_s \sim 16$) by [2] claimed the existence of arcs of metal poor C stars in the outer parts of M33.

2 Observations, analysis & results

New NIR observations of M33 have been obtained from UKIRT as part of a programme to survey luminous red stars in LG galaxies (PI Irwin). UKIRT data combine wide-field and good sensitivity improving considerably on former studies. A mosaic of 4 WFCAM tiles covering $\sim 3 \text{ deg}^2$ was observed with an average seeing of $1.07'' \pm 0.06''$. This allowed to reach sources as faint as $K_s = 18.32$ with $S/N = 10$ including most intermediate-age AGB stars. The data was dereddened assuming $E(B - V) = 0.07$ and using the [5] reddening law such that the absorption in each wave band is $A_J = 0.06$, $A_H = 0.04$ and $A_{K_s} = 0.02$.

The tip of the red giant branch (TRGB) is found at $K_s = 18.15$. The distribution of stars in the CMD ($J - K_s$, K_s) shows that foreground stars, O-rich and C-rich AGB stars occupy clearly distinct regions. Figure 1 shows confirmed long-period-variable (LPV) AGB stars from the cross-identification with the variability study by [6] as well as obscured sources observed by Spitzer.

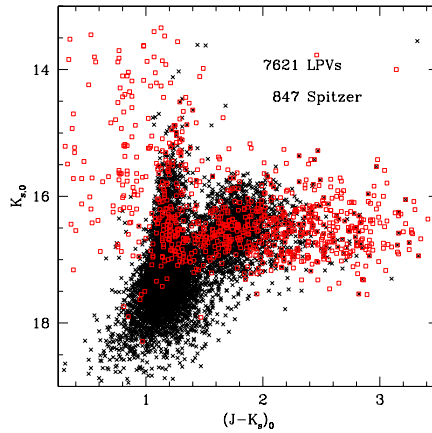


Fig. 1. CMD of NIR sources matched with LPVs candidates from Hartman et al. ([6]; crosses) and Spitzer detections (squares). The TRGB is at $K_s = 18.15$. C-rich AGB stars are redder than $J - K_s \sim 1.5$ while O-rich stars are bluer. Stars observed by Spitzer with $J - K_s < 1$ are likely supergiants.

The spatial distribution of supergiant stars is clumpy and extends asymmetrically to the NE while AGB stars trace a smoother distribution with hints of the major galaxy spiral arms. The ratio between C- and O-rich AGB stars (the C/M ratio) also outlines a ring-like feature and suggests a metallicity spread of $[\text{Fe}/\text{H}] = 0.6$ dex across the galaxy, using the [1] calibration, in agreement with the results by [9].

2.1 Structure & Extinction

By subdividing the galaxy disk into 4 concentric ellipses and 8 sectors we investigated the orientation as well as the contribution by differential extinction within the galaxy, if any. The peak of the magnitude and colour differences from the mean, for C stars, describe a sinusoidal pattern which indicates that stars in the NW of the galaxy are fainter than stars in the SE of it. This sinusoid is consistent with the distance moduli distribution derived by [7] in 10 different regions scattered within M33 suggesting that it is almost entirely a structure rather than an extinction effect.

2.2 Mean age and metallicity

The K_s magnitude distribution of stars within each sector of each ellipse has been fitted with theoretical distributions spanning a range of mean ages (2 – 10.6 Gyr) and mean metallicities ($Z = 0.0005 - 0.016$). The theoretical models used to create the distributions are those by [4]. This method was first used by [3] to investigate the stellar population of the Large Magellanic Cloud.

Maps of the best fit mean metallicity versus mean age and combined maps of best fit mean age and metallicity have been created separately for C-rich and O-rich AGB stars. These show an inhomogeneous distribution of age and metallicity. Note that relative values are much more significant than absolute values which can be model dependent.

The very central region of the galaxy or regions around it appear metal rich compared to the overall disk. In particular, C stars trace a disk/halo population which is metal poor ($[\text{Fe}/\text{H}] \leq -1.6$ dex) while the nucleus and other regions around it are as metal rich as $[\text{Fe}/\text{H}] \sim -1.2$ dex. There is an outer thick ring of stars on average 6 Gyr old or older. O-rich AGB stars also suggest an old (6 – 8.5 Gyr) and metal poor ($[\text{Fe}/\text{H}] \leq 0.5$ dex) outer ring while the centre of the galaxy is as young (1 – 5 Gyr) and metal rich ($[\text{Fe}/\text{H}] \geq 0.3$ dex). Although trends are the same for both C-rich and O-rich AGB stars, the latter show higher metallicity values but very similar ages.

3 Conclusions & Future studies

The K_s method is an efficient way to constraint the parameters of a galaxy stellar population using bright IR targets like AGB stars. The existence of a

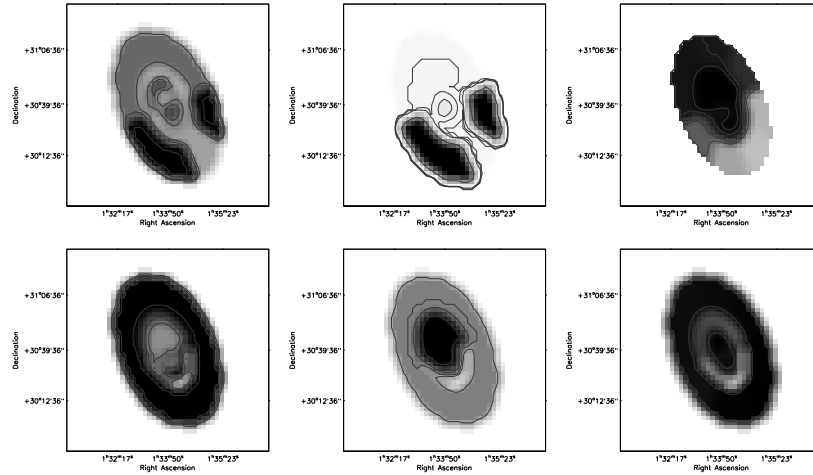


Fig. 2. Spatial distribution of the mean age of the stellar population of M33 (top), of the metallicity (middle) and of the statistical probability that expresses the confidence level of the previous distributions. These distributions have been constructed from the comparison between the observed K_s magnitude distribution of C-rich (top) and O-rich (bottom) AGB stars selected from the CMD. Darker regions correspond to higher numbers. North is up and East is left.

metallicity and age gradient throughout M33 is confirmed. The C/M ratio, mean age and metallicity show much more structure/substructures. The SE of the galaxy is closer to us; the position angle of bright/faint stars is in the direction of the galaxy warp. Many of the detected AGB stars are LPVs.

More galaxies have been observed within the same programme and will be soon analysed. Theoretical models are already good enough to fit entirely CMDs instead of just magnitude distributions. The study of galaxies well beyond the LG has to wait next generation facilities like JWST and E-ELT.

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